Fish Habitat Compensation to Achieve No Net Loss: Review of Past Practices and Proposed Future Directions

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FISH HABITAT COMPENSATION TO ACHIEVE NO NET LOSS: REVIEW OF PAST PRACTICES AND PROPOSED FUTURE DIRECTIONS

by

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TABLE OF CONTENTS

TABLE OF CONTENTS iii
ABSTRACT iv
RÉSUMÉ v
INTRODUCTION 1
BACKGROUND 2
CHALLENGES IN ACHIEVING NO NET LOSS 3
AUTHORIZATIONS 3
Required compensation ratios are often too small 3
Temporal losses in productive capacity due to avoidable time lags 3
Technical reviews of compensation project proposals are occasionally inadequate 4
Opportunities to address factors limiting production are sometimes overlooked 5
COMPLIANCE 5
Non-compliance with authorizations is common 5
Financial securities are not used to their full potential 6
COMPENSATION SCIENCE 7
CHALLENGES IN MEASURING NO-NET-LOSS 7
AUTHORIZATIONS 8
Authorizations often lack specific goals and objectives 8
MONITORING PROGRAMS 8
Designs of monitoring programs are often inappropriate to measure NNL 8
Frequency and duration of monitoring is usually insufficient to measure NNL 9
Inappropriate variables are often monitored 10
Statistical power is seldom considered in monitoring programs 11
Delineation of compensation sites is often unclear 11
CHALLENGES WITH ORGANIZATIONAL MEMORY, LEARNING, AND TRANSPARENCY 12
Transparency in decision-making 12
Improvements in learning and organizational memory 13
Improvements in program effectiveness evaluation and adaptive management 13
CONCLUSION 15
SUMMARY OF RECOMMENDATIONS 16
RECOMMENDATIONS FOR ACHIEVING NO-NET-LOSS 16
RECOMMENDATIONS FOR MEASURING NO-NET-LOSS 17
RECOMMENDATIONS FOR IMPROVING ORGANIZATIONAL MEMORY, LEARNING, AND TRANSPARENCY 18
LITERATURE CITED 20

ABSTRACT

Quigley, J.T., Harper, D.J., and Galbraith, R.V. 2006. Fish habitat compensation to achieve no net loss: review of past practices and proposed future directions. Can. Tech. Rep. Fish. Aquat. Sci. 2632: vi + 22 p.

Fisheries and Oceans Canada (DFO) implemented its Habitat Policy in 1986 with the guiding principle of no net loss (NNL) in productive capacity of fish habitat in Canada. Under the policy, productive capacity lost to harmful alteration, disruption, or destruction of fish habitat (HADD) is compensated for through proponent funded creation, restoration or enhancement of other habitats. Since 1986 more than 2,500 HADDs and associated compensatory projects have been authorized by DFO across Canada. In this paper we list and explain recommendations from a comprehensive assessment of the policy's effectiveness. The assessment included four components; a literature review, a detailed file review of authorizations issued from 1994 to 1997, a field audit of associated compensation projects for compliance with authorization requirements, and a quantitative evaluation of the effectiveness of projects in achieving NNL. Select cases demonstrated success in achieving NNL; however in the majority of cases, the results showed that significant net losses of habitat productive capacity are likely occurring. In this paper, recommendations for improvement in fish habitat compensation and achievement of NNL are made at the project as well as the institutional level. At the project level these include; adopting larger compensation ratios than those currently being required (i.e. minimum 2:1) that are based on productive capacity as well as area; instituting regular site monitoring during and after project and compensation construction with performance criteria that are well defined, quantitative and measurable; and monitoring a range of physical and biotic variables to create a composite picture of the habitat's productive capacity. At the institutional level recommendations include; developing regional lists of habitat specific monitoring variables for common project types and adoption of standard measurement methodologies to facilitate program effectiveness evaluation; incorporation of similar projects in similar habitats into adaptive management experiments to evaluate the effectiveness of best management practices; and the creation of a DFO monitoring unit at the regional and national level that enables analysis, reporting, and development of methodologies, education, and training to be implemented at the program level in a coordinated and consistent manner. The remaining recommendations for improvement center on three areas; those that will help achieve NNL, those that will help measure net changes in productive capacity, and those that will improve organizational memory, learning and transparency within DFO. The Habitat Policy remains integral to the protection of aquatic resources in Canada; however, it should be managed adaptively to ensure it is effective in achieving the goal of no net loss of habitat productivity.

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RÉSUMÉ

Quigley, J.T., Harper, D.J., and Galbraith, R.V. 2006. Fish habitat compensation to achieve no net loss: review of past practices and proposed future directions. Can. Tech. Rep. Fish. Aquat. Sci. 2632: vi + 22 p.

Pêches et Océans Canada (MPO) a mis en place sa politique de gestion des habitats du poisson en 1986 en la basant sur le principe directeur d'aucune perte nette (APN) de la capacité de production des habitats du poisson au Canada. En vertu de cette politique, les pertes de capacité de production résultant de la détérioration, de la destruction ou de la perturbation (DDP) de l'habitat du poisson doivent être compensées par la création, la restauration ou la mise en valeur d'autres habitats aux frais du promoteur. Depuis 1986, plus de 2 500 dossiers de DDP et de compensation associée ont été autorisés par le MPO au niveau national. Dans cet article, nous formulons et expliquons des recommandations après évaluation détaillée de l'efficacité de la politique. Cette évaluation comportait quatre composantes : une analyse bibliographique, un examen détaillé des autorisations passées, une vérification sur le terrain de quelques projets de compensation pour vérifier leur conformité aux exigences associées aux autorisations et une évaluation quantitative de l'efficacité des projets pour ce qui est de l'atteinte d'APN. Dans quelques cas, l'objectif d'APN a effectivement été atteint; cependant, dans la majorité des cas, les résultats ont mis en lumière une perte nette importante probable de la capacité productive de l'habitat. Dans cet article, nous formulons des recommandations pour l'amélioration de la compensation de l'habitat du poisson et l'atteinte de l'APN au niveau des projets et des institutions. Au niveau des projets, nous recommandons notamment : l'adoption de rapports de compensation plus importants que ceux présentement exigés (c.-à-d. d'un minimum de 2:1) et basés à la fois sur la capacité productive et sur la surface; la mise en place de visites régulières sur le site pendant et après le projet et des ouvrages de compensation associés à des critères de performance bien définis, quantitatifs et mesurables; la surveillance de toute une gamme de variables physiques et biotiques permettant de dresser un tableau composite de la capacité productive de l'habitat. Au niveau institutionnel, nous recommandons : l'élaboration de listes régionales de variables de surveillance spécifiques à chaque habitat par types de projet et l'adoption de méthodes de mesure normalisées afin de faciliter l'évaluation de l'efficacité des programmes. l'incorporation des projets similaires dans des habitats similaires à des expériences de gestion adaptatives visant à évaluer l'efficacité de diverses pratiques exemplaires; la création d'une unité de surveillance de MPO aux niveaux régional et national qui permettra l'analyse, la documentation et le développement de méthodologies, de l'éducation et de la formation Les autres recommandations concernent des améliorations dans trois domaines; celles qui contribueront à l'atteinte d'APN, celles qui contribueront à la mesure des changements nets de la capacité de production et celles qui contribueront à l'amélioration de la mémoire organisationnelle, l'apprentissage et la transparence au sein du MPO. La politique de gestion des habitats du poisson reste un élément essentiel de la protection des ressources aquatiques au

Canada; elle devrait cependant être gérée de manière adaptative pour faire en sorte qu'elle permette d'atteindre efficacement l'objectif d'aucune perte nette de la productivité de l'habitat.

INTRODUCTION

In recognition of the ever increasing human impacts on fish habitat, Fisheries and Oceans Canada (DFO) implemented the *Policy for the Management of Fish Habitat* (the Habitat Policy; DFO 1986). The overall objective of the Habitat Policy is the achievement of a net gain (NG) in the productive capacity of fish habitats. This objective is to be achieved by meeting three goals: 1) conservation of the current productive capacity of fish habitats; 2) restoration of damaged fish habitats; and 3) creation of new fish habitats (DFO, 1986).

To achieve the conservation goal, DFO applies the Habitat Policy's guiding principle of no net loss (NNL) when proposed development projects have the potential to result in a harmful alteration, disruption, or destruction (HADD) and a net loss of the productive capacity of fish habitat. Under this principle, DFO will require the proponent to relocate or redesign the proposed development to avoid the potential HADD or to fully mitigate any impacts the proposed development may have on fish habitat (DFO 1986; DFO 1998). DFO can authorize a HADD under Section 35(2) of the *Fisheries Act* if it cannot be fully mitigated, if the project is in the public's best interest, and if compensatory works can be developed to offset the HADD. In these circumstances, DFO will require the proponent to compensate for the unavoidable losses of productive capacity resulting from the HADD by creating or restoring habitat. DFO uses a hierarchy of preferences in selecting compensation options (DFO 1986; DFO 1998). These range from the most preferred option of creating or enhancing similar habitat to that affected by the HADD at or near the development site, to the least preferred option of artificial propagation of fish. The proponent is typically required to conduct follow-up monitoring to determine the effectiveness of the mitigation and compensation measures in achieving NNL. The intention of follow-up monitoring is to allow both the proponent and DFO to take an adaptive management approach to habitat compensation.

In this document we summarize the outcomes and recommendations of a recent evaluation program that examined habitat compensation projects across Canada. Our intent is to provide an integrated summary that will assist managers in improving upon habitat management approaches related to habitat compensation. There are three principle challenges DFO faces with respect to habitat compensation: (1) achieving NNL, (2) measuring NNL, (3) improving organizational memory, learning, and transparency in decision-making. A brief explanatory discussion and recommendations aimed at addressing each challenge follows. All recommendations are summarized in the concluding section of the paper.

BACKGROUND

Since the implementation of the Habitat Policy in 1986, more than 2,500 HADDs and associated compensation projects have been authorized by DFO across Canada (DFO 2002), yet DFO has conducted or commissioned only 10 studies evaluating a total of 103 projects (4% of authorized HADDs) to assess the performance of habitat compensation projects in achieving NNL (Harper and Quigley 2005a). The studies were largely limited in scope and assessed compensation projects that were specific to certain development activities, habitat types, or compensation techniques. For the most part, studies were more qualitative than quantitative in approach and remain outside the peer-reviewed literature (Harper and Quigley 2005a). The lack of quantitative studies evaluating the performance of habitat compensation projects in achieving NNL limits DFO's ability to adaptively manage its habitat conservation program and has raised concerns both within and outside the Department (Standing Committee on Public Accounts 1998, Auditor General of Canada 1997).

To address these concerns, a national evaluation program was initiated in 2000 to assess the performance of compensation projects in achieving NNL. It included four components; a literature review, a detailed file review, a compliance audit, and an effectiveness study. For the literature review, Harper and Quigley (2005a) compiled and reviewed all of the studies in the peer-reviewed and grey literature that have assessed habitat compensation projects to determine their success in achieving NNL. In the detailed file review, 124 authorizations for HADDs issued by DFO between 1994 and 1997 were collected and analysed. They provided an indication of the types of projects that have been authorized, what habitats have been impacted, and what approaches have been used in selecting, monitoring and evaluating compensation sites (Harper and Quigley 2005b). In the compliance audit, 52 of the 124 habitat compensation projects were field-inspected to assess compliance with biological, physical, and chemical requirements in authorizations (Quigley and Harper 2006a). In the effectiveness audit, 16 of the 52 projects examined in the compliance audit were quantitatively evaluated for achievement of NNL by comparing habitat productivity at treatment and reference sites (Quigley and Harper 2006b).

The evaluation program documented a variety of positive management practices relating to the authorization of HADDs and the implementation of effective habitat compensation. However, these evaluations also highlighted challenges in some areas, specifically; file management and record keeping, proponent compliance with authorization requirements, the use of quantitative monitoring procedures, and in the effectiveness of compensatory habitat in balancing losses resulting from HADDs. The Habitat Policy remains integral to the protection of aquatic resources in Canada, yet its implementation needs to be improved and should be managed adaptively (*sensu* Walters and Holling 1990).

CHALLENGES IN ACHIEVING NO NET LOSS

Every study that has examined the performance of compensation projects in achieving NNL has shown limited success (see Harper and Quigley 2005a for review). Quigley and Harper (2006b) showed that 63% of projects did not achieve NNL. This outcome stems from multiple causes including the content of authorizations and challenges with proponent compliance.

AUTHORIZATIONS

Required compensation ratios are often too small

Harper and Quigley (2005b) showed that over 80% of compensation projects evaluated required compensation ratios (compensation area to HADD area) in the authorization of less than 2:1 and that more than one quarter required compensation ratios of less than 1:1. Most compensation ratios did not vary with the quality of habitat affected by the HADD, contrary to recent policy direction (DFO 2002).

In most instances, compensation ratios should be greater than 1:1 to account for time lags in the development of productive capacity by new habitat and for uncertainty in project success (DFO 2002). Minns and Moore (2003) used a modelling approach to show that compensation ratios of 2:1 or greater will likely be required to achieve NNL in the face of uncertainty around productivity of compensation habitats. This finding was supported empirically by Quigley and Harper (2006b) who used productivity indices measured in real compensation projects to show that ratios of 2:1 are sufficient to achieve NNL in most (81%), but not all projects. This indicates that even if authorizations contained minimum ratios of 2:1, losses of habitat productivity could still occur as the ability to replace or replicate ecosystem functionality through compensation is limited.

Recommendations

1. In most instances compensation ratios should be larger that those currently being required (i.e. minimum 2:1) to increase the probability of attaining NNL, while recognizing that there may be innovative approaches to achieve highly productive compensation habitat that would meet the goal of NNL with a compensation ratio of less than 2:1. The compensation ratio should be increased in situations where uncertainty of compensation site effectiveness is high.
2. Compensation ratios should be based on the area and the productive capacity of the habitat lost as a result of the HADD consistent with policy direction (DFO 2002).

Temporal losses in productive capacity due to avoidable time lags

Construction of compensation habitat is often postponed until after the HADD has occurred, resulting in a temporal loss of productive capacity during this period (Quigley and Harper 2006b). This is, of course, in addition to temporal

losses that accrue as productivity remains low while the newly constructed compensation site matures. A solution to reducing temporal losses in productive capacity could be achieved by requiring the compensatory habitat to be constructed prior to the HADD.

Recommendation

3. Where possible, require that compensatory habitat be constructed prior to or concurrent with the HADD.

Technical reviews of compensation project proposals are occasionally inadequate

High failure rates of habitat compensation projects are common when projects are poorly designed for their local geophysical setting, when large scale landscape processes such as floods or droughts are not considered (Frissell and Nawa 1992; Lewis et al. 1996), or when appropriate maintenance programs are not employed. Examples of the above were present in many types of compensation projects reviewed by Quigley and Harper (2006a) and were particularly prevalent in riparian compensation projects. In some cases, compensation works that were poorly designed resulted in additional, unauthorized HADDs (Quigley and Harper 2006a).

These situations could be identified and avoided through a technical review of a proposal's engineering and hydrological soundness. Similarly, reviews of the local environmental limitations (e.g. suitability of a riparian planting plan to site conditions) with regard to climate, soil and hydrological setting would likely reduce failure rates significantly. Generally, the success of compensation projects could be improved by enhancing the rigour of the technical reviews of compensation proposals, using a multi-disciplinary approach involving a range of DFO experts including biologists, engineers, and hydrologists.

Further, sustainability of the compensation project should be factored into the technical review of project siting. Many projects are positioned in landscape locations that do not ensure sustainability (i.e. site is prone to isolation or destruction during channel forming flood events; Quigley and Harper 2006a). The impact to the landscape from development activities (i.e. the HADD) generally last in perpetuity, while it remains uncertain whether compensation projects persist over the long term (>50 years). In addition to appropriate siting, technical reviews of compensation proposals should also ensure appropriate maintenance programs are in place to improve sustainability of compensatory works.

Recommendations

4. Technical reviews of compensation proposals should include engineering and hydrological assessments, in addition to biological considerations.

5. Technical reviews of compensation proposals should consider the sustainability of the project from a landscape perspective as well as local environmental limitations at the proposed sites.
6. Technical reviews of compensation proposals should ensure maintenance programs are appropriately scaled and designed.

Opportunities to address factors limiting production are sometimes overlooked

Compensation sites are too often selected opportunistically (Quigley and Harper 2006a). Ideally, watershed-scale compensation plans should be developed that identify limiting factors (e.g. fish movement barriers), high-value habitats that should be protected from HADDs, and a prioritized list of potential compensation options that can be used to address limiting factors. These plans need not be overly complex, and for many watersheds would consist of a short statement describing likely limiting factors and a simple list of priority sites for habitat compensation (e.g. a perched culvert). Such a strategy would assist in ensuring that authorized HADDs occur in low value habitats when possible and that associated compensation works target existing critical production bottlenecks.

Moreover, compensation options to achieve like-for-like habitat may not be the most effective choice. In some instances the largest productive capacity gains can be made by moving down the hierarchy of preferences to address factors limiting other populations of interest in the same or another watershed (Quigley and Harper 2006b). These cases often involve decisions about tradeoffs between different habitat types and should be based on production estimates at a common life-history stage using a decision analysis framework (Pearson et al. 2005).

Recommendations

7. Develop watershed-scale compensation plans identifying limiting factors (e.g. fish movement barriers), high-value habitats that should be protected from HADDs, and a prioritized list of potential compensation options that can be used to address limiting factors.
8. Consider compensation options that are lower in the hierarchy of preferences if these have potential for larger gains in habitat productive capacity.

COMPLIANCE

Non-compliance with authorizations is common

Project proponents frequently failed to comply with DFO's HADD authorizations, particularly with respect to habitat areas and monitoring requirements. Quigley and Harper (2006a) found 86% of the 52 projects they assessed had either larger HADD or smaller compensation areas than required in their authorizations. Additionally, engineering drawings for almost 40% of

projects showed either larger HADD or smaller compensation areas than required areas stated in their authorizations. In those with discrepancies, HADDs on the engineered drawings averaged approximately double the size permitted in the text of the authorization (Quigley and Harper 2006b).

Compliance with monitoring requirements was similarly low; approximately 43% of required monitoring reports were submitted by proponents (Harper and Quigley 2005b). Follow up monitoring by DFO is also not common (Drodge et al. 1999). Furthermore, Quigley and Harper (2006a) showed that enforcement activities are rarely undertaken to address instances of non-compliance with authorization conditions.

DFO's ability to determine compliance with authorizations would improve with greater attention in three areas. First, enhanced effort should be allocated to ensure monitoring reports are completed. Second, an office review of these monitoring reports with respect to conformance with the authorization requirements would enhance compliance when followed up with the proponent. Finally, a DFO field audit of a subset of these monitoring reports, to evaluate how accurately they reflect actual conditions, would provide valuable feedback to improve compliance. Similar to the proposal phase, compliance could be improved by enhancing the rigour of technical reviews of monitoring reports through a multi-disciplinary approach involving a range of DFO experts. Also, partnerships with other sectors of DFO (e.g. Conservation and Protection, Science), the public, partners (e.g. stewardship groups), First Nations and government agencies would assist in implementing field audits.

Recommendations

9. Compare compensation ratios calculated from construction drawings to those in the HADD authorization to ensure they are equivalent.

10. Ensure regular site monitoring is a condition of the authorization and is completed by the proponent or an independent, appropriately qualified environmental monitor.

11. Monitoring reports should be reviewed by DFO to ensure compliance with the terms of the authorization.

12. DFO should increase their field presence and regularly audit sites to ensure monitoring information is accurate and identify and reduce instances of non-compliance.

13. Enforcement activities (verbal and written notifications and warnings, investigations, court-ordered remediation, etc.) should be pursued in instances of non-compliance.

Financial securities are not used to their full potential

Financial securities (e.g. letters of credit) can be a useful tool to increase compliance (Zedler et al. 2001). The purpose of financial securities is to ensure

completion of required compensation works and monitoring programs. However, financial securities are not retained very often; 34% of the 124 authorizations covered by the file review required financial securities (Harper and Quigley 2005b). Moreover, none of these financial securities were exercised, even though non-compliance was prevalent (Quigley and Harper 2006b).

Recommendations

14. Financial securities should be retained more frequently to improve proponent compliance with the conditions of authorizations.

15. Exercise financial securities when incidences of non-compliance cannot be reconciled with the proponent.

COMPENSATION SCIENCE

Compensation studies suggest that ecosystem function is difficult to replicate (Quigley and Harper 2006b), and it is important to acknowledge it is simply not possible to compensate for some habitats. Therefore, the option to compensate for HADDs may not be viable for some development proposals, demanding careful exploration of alternative options including re-design, re-location or rejection.

Recommendations

16. Scientific research on habitat compensation should be undertaken in partnership with DFO Science Branch and academic institutions to improve the scientific defensibility of habitat compensation decisions by DFO.

17. In certain cases when compensation success is highly uncertain or unlikely, DFO should carefully consider whether a HADD authorization should be issued (i.e. acknowledging the limitations of compensation).

CHALLENGES IN MEASURING NO-NET-LOSS

The file review showed that a NNL determination for many authorizations could not be made based on monitoring results, even when the work was completed and all reports were available (Harper and Quigley 2005b). The primary problems were poor parameter selection, lack of a rigorous experimental design (e.g. controls, replicates, baseline data), and the use of inadequate methodology (Harper and Quigley 2005b). It is a common misconception that the impact of habitat alterations can be assessed merely by monitoring the treatment site before and after the alteration (Minns et al. 1996). Increased scientific rigor in monitoring is undoubtedly more expensive and time consuming than current approaches, but monitoring that is incapable of assessing NNL achievement, its primary goal, wastes scarce financial and human resources on collecting data that cannot be applied. A monitoring and assessment guidebook (Pearson et al. 2005) provides detailed advice on these and related matters and includes several case studies to illustrate their application. Its principles and concepts should be

applied to ensure that NNL evaluations are quantitative and scientifically defensible and that results are comparable across projects to permit adaptive management through program effectiveness evaluation. In the following sections we outline some of the more common problems and make specific recommendations for each.

AUTHORIZATIONS

Authorizations often lack specific goals and objectives

Assessments of NNL, based upon 124 file reviews, were possible for only a small minority of projects (Harper and Quigley 2005b). The primary goal of a compensation project, the achievement of NNL, was rarely stated and performance criteria were often non-existent or too vague to be relevant (Harper and Quigley 2005b). Good monitoring is facilitated by authorizations that specify rationales, goals, performance criteria, and basic methodologies; all were commonly lacking in those authorization files reviewed (Harper and Quigley 2005b). Description and quantification of the habitat to be altered and fish species likely to be affected by the HADD or compensation strategies were often not even noted, which complicates the ability to determine NNL.

Recommendation

18. Authorizations should contain a section that clearly states objectives, performance criteria and goals, for both the HADD and compensatory habitats, which are well defined, quantitative and measurable and linked to the achievement of NNL.

MONITORING PROGRAMS

Designs of monitoring programs are often inappropriate to measure NNL

NNL achievement could not be assessed for 88% of the 124 files reviewed due to poorly designed or executed monitoring programs (Harper and Quigley 2005b). In the majority of cases, field work was completed but lacked one or more components critical to NNL assessment (e.g. the compensation site was monitored but the HADD site was not), and in some instances no field sampling was conducted.

Employing an appropriate experimental design is critical to separating effects of a project from those of other influences. Key elements in experimental design include replicates and reference sites. The most robust and powerful experimental designs for assessing NNL involve Before, After, Control, Impact (BACI) comparisons. They require that variables be measured 'before' and 'after' the treatment (project) at both 'control' and 'impact' (project) sites (see Pearson et al. 2005 for detailed discussion). BACI designs allow observed trends in a project site to be legitimately attributed on or off-site influences.

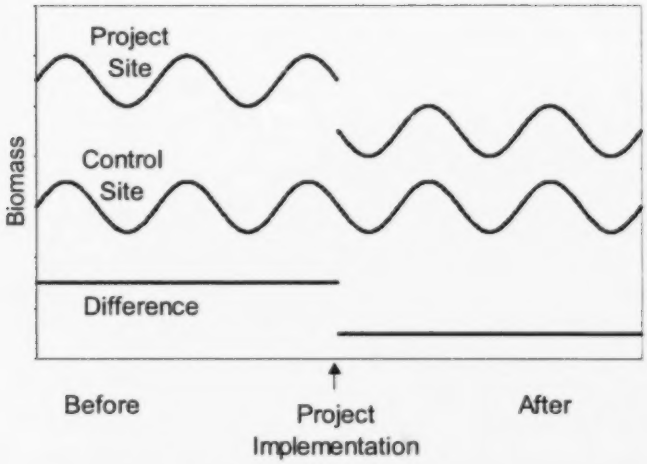

Figure 1: Hypothetical data from a BACI experimental design applied to biomass. Mean biomass before and after a project, measured at the project site and a control site, cycles seasonally and is higher at the project site. The difference between control and project sites remains constant within the before and after periods, but decreases in response to project implementation, providing strong evidence for a negative project impact. Without the control site, the change could not legitimately be attributed to the project's effects (adapted from Stewart-Oaten et al. 1986).

Recommendations

19. Require the use of appropriate experimental designs, including control sites, baseline data and replicates to measure NNL for compensation projects.

20. Guidance documents (e.g. Pearson et al. 2005) should be produced to strengthen the experimental design of monitoring programs, and partnerships should be developed with internal DFO experts (e.g. Science Branch) for technical review of monitoring programs.

Frequency and duration of monitoring is usually insufficient to measure NNL

As above, NNL achievement could not be assessed for the majority of the 124 files reviewed due to poorly designed or executed monitoring programs, including insufficient frequency and/or duration of monitoring (Harper and Quigley 2005b). Detecting change against the background noise of natural variation depends upon sampling frequently enough for long enough. In the past, pre-project monitoring duration has typically been limited to a single year if it has occurred at all. This practice prevents the separation of project impacts from natural year-to-year variation, a problem that will plague both proponents and approval agencies as unmeasured annual variation can either mask or

exaggerate project effects. Even two years of pre-project data offers very limited power to detect changes due to project effects (Pearson et al. 2005).

The lifespan of compensatory works should be commensurate to the longevity of the HADD. The impacts to the landscape from development (e.g. highways, urban development) generally last into perpetuity. However, whether compensation efforts persist over the long term (> 50 years) remains uncertain. In practice, monitoring has typically extended for less than four years past project construction (Harper and Quigley 2005b). Post-project monitoring duration should be linked to rates of habitat change and life cycle duration of target species. It should also be linked to project size, complexity, and/or potential for negative effects and ideally extend for 10 years or two life cycles of target species. However, monitoring need not be continuous (Bryant 1995, Hunt 1976). One way to achieve longer monitoring periods without a large increase in cost is to stagger monitoring over longer durations (e.g. same number of sampling events stretched over a longer time period). This will likely provide a better picture of the projects long-term nature, as it allows greater maturity and/or recovery time.

Monitoring frequency should be the same in before and after periods to ensure that cyclic patterns (e.g. seasonal changes) are represented in both data sets in the same manner (Smith et al. 1993).

Recommendations

21. Pre-project monitoring periods of two years should be used whenever possible (one year minimum) and post project monitoring should be scaled to project size and/or complexity, as well as to its potential for causing negative impacts. Ideally, this would extend for 10 years or two life cycles of target species in two-year pulses.

22. Monitoring frequency should be the same in before and after periods and preferably more than once per year.

Inappropriate variables are often monitored

Habitat quantity (i.e. area) is often the sole indicator of NNL in monitoring programs, rather than a commiserate measure of habitat quality which would provide a more robust picture of NNL success (Quigley and Harper 2006b). To assess NNL, a monitoring program must quantify a habitat's productive capacity as a function of its size and its maximum productivity per unit area.

To evaluate habitat productivity, the best approach involves measuring a variety of physical and biotic variables including production of multiple taxa representing several trophic levels. This provides a more complete picture of habitat productive capacity upon which to base evaluations of project success and/or achievement of NNL (Minns 1997, Pearson et al. 2005). Selection of single variables at only one trophic level as the performance measure to quantify

habitat quality limits the ability to detect change, and is a particular challenge when production of target species (e.g. fish) is a poor indicator of capacity due to high natural variation, movement in or out of the study area, and/or sampling difficulties (Quigley and Harper 2006b, Pearson et al. 2005).

Recommendations

23. Monitoring programs should include measures of both habitat quantity and habitat quality to determine NNL.

24. To evaluate habitat quality, a range of physical and biotic variables should be monitored to create a composite picture of the habitat's productive capacity.

Statistical power is seldom considered in monitoring programs

Statistical power is expressed as the probability that a given size of impact can be detected, and was rarely, if ever, considered in the projects examined by Quigley and Harper (2006b). Monitoring studies, following a long tradition in ecological research, virtually always focus on minimizing the probability of falsely detecting an effect where none really exists (committing a type I error), arbitrarily setting its risk at 5% (α=0.05). This is generally appropriate for research, but will often mislead management decisions by greatly increasing the risk of failing to detect real effects (type II error; Peterman 1990, Mapstone 1995). For example, Mapstone (1995) reports that many environmental impact assessments conclude that a development had no effect when an 80-100% change in the measured variable would have been required to find one. Statistical power of tests and the relative risks of type I and type II errors should be considered and estimated *before* sampling begins for large or complex compensation projects. The best way to increase power is to increase sample size.

Recommendation

25. Power analyses and calculation of required sample size should be included in design of monitoring programs, especially for large and/or complex projects.

Delineation of compensation sites is often unclear

Assessment of NNL is critically dependant upon measurements of HADD and compensation site areas. Unless these are clearly delineated from the outset, boundaries become indistinct as a site changes though succession or natural disturbance. Difficulty in identifying site boundaries was a recurrent challenge in the Quigley and Harper (2006a) field audits, contributing to difficulty in determining NNL.

Moreover, increased public awareness of fish and fish habitat issues is likely to have general and widespread benefits for the environment (Grese et al. 2000, Geist and Galatowitsch 1999). Clearly marked habitat projects will increase their presence in the public view and promote this awareness.

Documenting the contribution of habitat projects to public understanding of conservation issues is important to understanding the full value of projects and should be considered for compensation projects in highly settled landscapes. Basic monitoring methods suitable for gauging public awareness and support are presented in Pearson et al. (2005).

Recommendations

26. HADD areas and compensatory habitat, including riparian plantings, should be clearly identified (e.g. flagging tape, marked stakes, signs, etc.) and georeferenced by GPS so that environmental monitors, DFO, and proponents can effectively locate the perimeters of these habitats.

27. Post signs at compensation sites to describe the project, its goals, and the fish species affected by the HADD and compensatory habitat.

CHALLENGES WITH ORGANIZATIONAL MEMORY, LEARNING, AND TRANSPARENCY

Transparency in decision-making

Information requirements for habitat management decision-making varied widely across Canada, as did the quality of information submitted (Harper and Quigley 2005b). This contributed to inconsistencies in decision-making and lack of certainty for the public with respect to what information requirements are necessary for DFO to make a decision and why. Efficiencies in the referral process would be gained if referral and habitat compensation information requirements were standardized and communicated to proponents. Improvements in decision-making would decrease time lags resulting from back and forth communications with proponents and would improve file management.

Rationale for the magnitude and particulars of financial securities are often unclear (Harper and Quigley 2005b). The amount of financial security required for compensation projects was not related to the size or type of project and varied considerably (Harper and Quigley 2004b). Pre-impact assessments completed by a consultant/proponent should itemize the compensation costs including materials, labour and machinery. This information would allow DFO to accurately set an amount for a financial security, in turn improving the defensibility of decisions made. It also allows for an opportunity for a cost/benefit analysis that would provide DFO with the ability to improve the cost-effectiveness of compensation and monitoring in subsequent projects, thus decreasing the costs to the proponent.

Recommendations

28. Develop checklists and booklets with step-by-step instructions for proponents on how to complete DFO applications and to clarify procedures and formats for the submission of proposals.

29. Increase training and outreach to industry, the public and staff on information requirements, compensation approaches and monitoring strategies to improve the quality of submissions.

30. Record the costs of compensation works and monitoring and consider them in establishing financial security requirements.

Improvements in learning and organizational memory

Few of the reviewed project files contained documentation of rationales used by DFO to make decisions regarding HADD acceptability or selection of compensation options (Harper and Quigley 2005b). The lack of documentation leaves DFO vulnerable to criticism from proponents and the public regarding the consistency and transparency of fish habitat management. It also compromises DFO's corporate memory, limits its organizational learning potential, and hampers its ability to effectively assess the outcomes of its decisions and manage adaptively.

Many of the 124 files reviewed by Harper and Quigley (2005b) contained only the authorization and limited correspondence, and more than 200 monitoring reports were never submitted to DFO. Corporate memory suffered on many files due to lack of staff continuity and variable file management such that the file history, lessons learned and outstanding proponent requirements were compromised at times of staff turnover. Without a coherent chronology of events, including brief descriptions of meetings, decisions-making, and monitoring reports DFO will be poorly equipped to deal with staff turnover, to defend itself in legal challenges, or to mount prosecutions.

Recommendations

31. Develop and use a standard form to document rationales for why an impact was considered a HADD, why it was authorized, and why a particular compensation option was chosen.

32. Include a schedule of milestones for project construction, compensation and monitoring in the authorization file.

Improvements in program effectiveness evaluation and adaptive management

NNL is not routinely tracked or assessed on regional and national scales (Harper and Quigley 2005a). Choices of variables and measurement methods vary widely among compensation projects. Lack of standardization prevents projects from being directly compared or assessed statistically, and is a major barrier to program level monitoring and evaluation (Pearson et al. 2005).

DFO could benefit from scientifically-defensible regional and national monitoring and evaluation programs through which the effectiveness of mitigation and compensation measures in achieving NNL would be tracked on a continual

basis. A model for such programs is presented in Pearson et al. (2005). Briefly, results from many project-level assessments are combined, statistically assessed and compared, allowing managers to rigorously evaluate new habitat compensation techniques and management approaches using active adaptive management. Authorizations for small HADDs (e.g. culvert replacements) and non-compensatory stewardship projects are assessed using basic routine monitoring. This includes information on compliance and simple indicators of effectiveness. Site effectiveness monitoring, used in authorizations of larger HADDs, uses formal experimental designs, and provides quantitative information on the productive capacity of habitat, allowing managers to assess NNL at the site scale. The third level, program effectiveness evaluation, occurs at larger scales and requires that practitioners employ consistent methodologies and experimental designs among projects and that their monitoring and evaluation data is accessible in a central database.

Other important information for the database would include the type and location of habitats impacted, what compensation was required and associated ratios for different habitat types, project costs, and compliance tracking. While a database currently exists to track and record basic information about authorizations (DFO 2003), it needs to be significantly expanded to enable NNL assessment. Additional benefits would include the ability to analyze trends and patterns in habitat compensation across Canada. Database design and examples of simple and complex queries are provided elsewhere (Harper et al. 2001). Obviously a considerable investment in both human and financial resources is required to successfully implement program effectiveness evaluation. However, in the long term an adaptive management approach will result in the adoption of proven cost-effective methods and more effective use of resources.

Recommendations

33. Develop regional lists of habitat specific monitoring variables for common project types and adopt standard measurement methodologies to facilitate program effectiveness evaluation.

34. Incorporate similar projects in similar habitats into adaptive management experiments to evaluate the effectiveness of best management practices.

35. Establish a central repository at Regional Headquarters for copies of all project documentation.

36. Enter authorization and compensation project information into a central database accessible at both the area and regional level to track gains and losses in habitat, due dates for monitoring reports, and to facilitate compilation of results for program effectiveness evaluation.

37. Publish annual reports on trends and patterns in habitat compensation, as well as achievement of NNL.

CONCLUSION

All of these recommendations are one step in the *adaptive management* process. In order to be effectively implemented we advocate ongoing adjustment and refinements to these proposed management practices and policies through continual evaluation and adjustment. Adaptive management and program effectiveness evaluation have many benefits, from highlighting our successes, to learning from past mistakes, to enhancing DFO's core expertise. The results are also transferable to other aspects of the Department such as enforcement (expert witness testimony, court ordered remediation), and enhances informed reviews of development and compensation proposals. Incorporating informed changes from program level evaluation can ultimately improve our management practices as we gain better understanding of their consequences. Overall, recognition and implementation of these recommendations will allow the Habitat Policy to be managed adaptively, ensuring it is effective in achieving the goal of no net loss of habitat productivity in Canada.

Recommendations

38. Create a DFO monitoring and program evaluation unit at the regional and national level that enables program assessment and improvement through performance evaluations in a clear and defensible manner. This would enable analysis and interpretation of monitoring information to form recommendations on how management approaches are functioning and where improvements can be made.

39. Initiate regional and national working groups to coordinate and standardize monitoring activities, reporting, methodologies, and training to be implemented at a program level in a coordinated and consistent manner.

SUMMARY OF RECOMMENDATIONS

RECOMMENDATIONS FOR ACHIEVING NO-NET-LOSS

1. In most instances compensation ratios should be larger that those currently being required (i.e. minimum 2:1) to increase the probability of attaining NNL, while recognizing that there may be innovative approaches to achieve highly productive compensation habitat that would meet the goal of NNL with a compensation ratio of less than 2:1. The compensation ratio should be increased in situations where uncertainty of compensation site effectiveness is high.
2. Compensation ratios should be based on the area and the productive capacity of the habitat lost as a result of the HADD consistent with policy direction (DFO 2002).
3. Where possible, require that compensatory habitat be constructed prior to or concurrent with the HADD.
4. Technical reviews of compensation proposals should include engineering and hydrological assessments, in addition to biological considerations.
5. Technical reviews of compensation proposals should consider the sustainability of the project from a landscape perspective as well as local environmental limitations at the proposed sites.
6. Technical reviews of compensation proposals should ensure maintenance programs are appropriately scaled and designed.
7. Develop watershed-scale compensation plans identifying limiting factors (e.g. fish movement barriers), high-value habitats that should be protected from HADDs, and a prioritized list of potential compensation options that can be used to address limiting factors.
8. Consider compensation options that are lower in the hierarchy of preferences if these have potential for larger gains in habitat productive capacity.
9. Compare compensation ratios calculated from construction drawings to those in the HADD authorization to ensure they are equivalent.
10. Ensure regular site monitoring is a condition of the authorization and is completed by the proponent or an independent environmental monitor.
11. Monitoring reports should be reviewed by DFO to ensure compliance with the terms of the authorization.
12. DFO should increase their field presence and regularly audit sites to ensure monitoring information is accurate and identify and reduce instances of non-compliance.

13. Enforcement activities (verbal and written notifications and warnings, investigations, court-ordered remediation, etc.) should be pursued in instances of non-compliance.

14. Financial securities should be retained more frequently to improve proponent compliance with the conditions of authorizations.

15. Exercise financial securities when incidences of non-compliance cannot be reconciled with the proponent.

16. Scientific research on habitat compensation should be undertaken in partnership with DFO Science Branch and academic institutions to improve the scientific defensibility of habitat compensation decisions by DFO.

17. In certain cases when compensation success is highly uncertain or unlikely, DFO should carefully consider whether a HADD authorization should be issued (i.e. acknowledging the limitations of compensation).

RECOMMENDATIONS FOR MEASURING NO-NET-LOSS

18. Authorizations should contain a section that clearly states objectives, performance criteria and goals, for both the HADD and compensatory habitats, which are well defined, quantitative and measurable and linked to the achievement of NNL.

19. Require the use of appropriate experimental designs, including control sites, baseline data and replicates to measure NNL for compensation projects.

20. Guidance documents (e.g. Pearson et al. 2005) should be produced to strengthen the experimental design of monitoring programs, and partnerships should be developed with internal DFO experts (e.g. Science Branch) for technical review of monitoring programs.

21. Pre-project monitoring periods of two years should be used whenever possible (one year minimum) and post project monitoring should be scaled to project size and/or complexity, as well as to its potential for causing negative impacts. Ideally, this would extend for 10 years or two life cycles of target species in two-year pulses.

22. Monitoring frequency should be the same in before and after periods and preferably more than once per year.

23. Monitoring programs should include measures of both habitat quantity and habitat quality to determine NNL.

24. To evaluate habitat quality, a range of physical and biotic variables should be monitored to create a composite picture of the habitat's productive capacity.

25. Power analyses and calculation of required sample size should be included in design of monitoring programs, especially for large and/or complex projects.

26. HADD areas and compensatory habitat, including riparian plantings, should be clearly identified (e.g. flagging tape, marked stakes, signs, etc.) and georeferenced by GPS so that environmental monitors, DFO, and proponents can effectively locate the perimeters of these habitats.

27. Post signs at compensation sites to describe the project, its goals, and the fish species affected by the HADD and compensatory habitat.

RECOMMENDATIONS FOR IMPROVING ORGANIZATIONAL MEMORY, LEARNING, AND TRANSPARENCY

28. Develop checklists and booklets with step-by-step instructions for proponents on how to complete DFO applications and to clarify procedures and formats for the submission of proposals.

29. Increase training and outreach to industry, the public and staff on information requirements, compensation approaches and monitoring strategies to improve the quality of submissions.

30. Record the costs of compensation works and monitoring and consider them in establishing financial security requirements.

31. Develop and use a standard form to document rationales for why an impact was considered a HADD, why it was authorized, and why a particular compensation option was chosen.

32. Include a schedule of milestones for project construction, compensation and monitoring in the authorization file.

33. Develop regional lists of habitat specific monitoring variables for common project types and adopt standard measurement methodologies to facilitate program effectiveness evaluation.

34. Incorporate similar projects in similar habitats into adaptive management experiments to evaluate the effectiveness of best management practices.

35. Establish a central repository at Regional Headquarters for copies of all project documentation.

36. Enter authorization and compensation project information into a central database accessible at both the area and regional level to track gains and losses in habitat, due dates for monitoring reports, and to facilitate compilation of results for program effectiveness evaluation.

37. Publish annual reports on trends and patterns in habitat compensation, as well as achievement of NNL.

38. Create a DFO monitoring and program evaluation unit at the regional and national level that enables program assessment and improvement through performance evaluations in a clear and defensible manner. This would enable analysis and interpretation of monitoring information to form recommendations on how management approaches are functioning and where improvements can be made.

39. Initiate regional and national working groups to coordinate and standardize monitoring activities, reporting, methodologies, and training to be implemented at a program level in a coordinated and consistent manner.

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